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Investigating the Effect of Meat Level and Processing Conditions on Quality Characteristics of Extruded Chicken Meat Noodles Using Response Surface Methodology

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ABSTRACT

A three factor three level central composite design was adopted to determine interactive effects of meat level (55-65%), steaming time (12-18 minutes) and drying time (7-9 hrs) on pH, moisture, protein content, fat content and other quality characteristics (Hardness, adhesiveness, total colour change and overall acceptability) of extruded chicken noodles. Moisture, protein, fat level and total colour change was found to be increased with increase in meat level while decreased with increasing processing conditions. However hardness decreased with increasing interaction of meat level and steaming time while increased with interaction of meat level and drying time and inverse were true for adhesiveness. Overall acceptability and pH had negative correlation with interactions. pH showed increasing trend with increase in processing conditions. The models for moisture, pH, protein, fat percentage, allokramer hardness, adhesiveness, total colour change and overall acceptability had the R square values of 0.91, 0.81, 0.83, 0.81, 0.87, 0.91, 0.82 and 0.94, respectively. 120 g (60%) meat level, 15 min steaming time and 9 hrs drying time were found to be optimized level on the basis of desirability plots for the development of chicken noodles.

Keywords: Chicken noodles, Hardness of noodles, Processing conditions, Response Surface Methodology

Snack, defined as a light meal eaten between regular meals include a broad range of products that can take many forms such as biscuits, caruncles and noodles. Noodles are an important part of the diet in many countries of eastern and south eastern Asia, accounting for approximately one third of Australia's bread wheat exports and about 40% of wheat consumed in Asian countries (Hou and Kruk, 1998). Asian noodles are not made exclusively of wheat, many are made from rice, buckwheat, and starches derived from the mung bean and potato for example. Noodles based on wheat are prepared mainly from three basic ingredients; flour, water, and salt. Extrusion cooking is continuous mixing, forming, versatile and low cost process and raw material in this process undergo conversion of chemical and structural transformations, such as starch gelatinization, protein denaturation, complex formation between amylose and lipids, and degradation reactions of vitamins, pigments etc. (Ilo and Berghofer, 1999) reduction of microbial counts, and improvement in digestibility and biological value of proteins (Martin-Cabrejas *et al.* 1999). Cereal grains are low in protein and deficient in essential amino acids such as lysine, tryptophan and threonine (Chaiyakul *et al.* 2009). Thus, proteineous raw material needs to be incorporated to ensure better nutritional quality of the noodles. Introduction of meat based noodles may solve current protein deficit with improvement of nutritional quality through the supply of essential amino acids. The spent hen meat is very tough in comparison to those of broilers and roasters (Baker *et al.* 1969) due to its higher collagen content, and is thus not well accepted by the consumers. Therefore, this meat needs to be tenderized before its use in product preparation.

Response surface methodology (RSM), a powerful mathematical and statistical technique for testing multiple process variables and their interactive and quadratic effects, is useful in solving multivariable equations obtained from experiments simultaneously. In the analysis of interactions between the responses (dependent variables) and the factors (independent variables) of experiment, this technique provides an advantage of the reduction in the number of experiments as compared to the full experimental design (Shih *et al.* 2008; Tiwari *et al.* 2008; Murphy *et al.* 2004; Ghodke *et al.* 2009) has been used for the simultaneous analysis of the effects of process parameters in fresh meat processing (Jakobsen and Bertelsen, 2000) and also in some meat products (Desmond *et al.* 1998; Hsu and Chung, 2000). According to these researches, RSM can help in predicting the combined effects of meat level and processing conditions on moisture, pH, protein, fat level, AlloKramer hardness, adhesiveness, total colour change and overall acceptability of *meat noodles*. In present study meat level (110-130g) and processing conditions; drying time (7-9 hrs) and steaming time (12-18min) were independent variables while physicochemical properties such as moisture, pH, protein, fat content, AlloKramer hardness, adhesiveness, total colour change and overall acceptability were dependent variable and these independent variables were optimized using central composite design of response surface methodology.

The aim of the present work is to determine the combined effect of meat level steaming and drying time on moisture, pH, protein, fat content, AlloKramer hardness, adhesiveness, total colour change and overall acceptability of chicken noodles and to develop mathematical models to find the optimum percentages of these ingredients for these criteria by using RSM. These models will provide a new approach for proposing optimum levels of meat level and processing conditions in order to produce standard products preferred by the consumers.

MATERIAL AND METHODS

Chemicals and other materials

All chemicals used were procured from standard firms like SRL, Fisher Scientific, CDH, HiMedia, Sigma-Aldrich etc. Meat samples required in the experiment was obtained from spent layer fowls slaughtered as per standard procedure in the experimental slaughterhouse of Department of Livestock Products Technology, College of Veterinary Science, GADVASU, Ludhiana, Punjab, India. The refined saffola oil (Manufactured and Packed by Marico Ltd., Mumbai, India), Refined wheat flour (Maida) spices, Table salt (Tata Chemicals Ltd., Mumbai, India), tetra sodium pyrophosphate (HiMedia Laboratories Pvt., Ltd., Mumbai, India), Low density polyethylene (LDPE) were procured from local market of Ludhiana and reputed firms.

Tenderization of meat

Frozen meat samples were taken out as per requirement and cut into smaller cubes after partial thawing in a refrigerator (4±1°C). The meat chunks were then tenderized using marinade containing calcium chloride (0.15M) and papain (0.25%) and kept under refrigeration temperature for 40 hrs (Biswas *et al.* 2009). Tenderized meat was washed repeatedly in distilled water, packed in LDPE bags and then frozen at -18±1°C for subsequent use.

Chicken noodles preparation

The tenderized frozen meat samples were cut into small chunks after partial thawing in a refrigerator and double minced through a meat mincer (Kalsi motors, Ludhiana, India) using 6 mm plate. The minced meat sample was blended with salt, tetra-sodium pyrophosphate (TSPP), refined vegetable oil, spice mix and refined wheat flour. Three coded level were incorporated in design and total of 20 combinations with six central points were obtained based on three-factor three levels (Table 1.) central composite experimental design of Response Surface Methodology.

Table 1: Experimental range levels of three independent variables in terms of actual values

Variables	Symbols	Coded variable levels				
		-α	-1	0	+1	+ α
Meat level (%)	X_1	103.182	110	120	130	136.818
Steaming time (min)	X_2	9.95	12	15	18	20.045
Drying time (hr)	X_3	6.32	7	8	9	9.68

-α- minimum value and +α- maximum value

Products from these 20 different combinations were prepared. The level of refined wheat flour (Maida) remained constant (100 g) for all samples, while levels of meat were determined based on preliminary trials as mentioned under the Table 1. All other ingredients namely salt, STPP, refined vegetable oil, spice mix were added at 3, 0.3, 4 and 1.5 per cent level, respectively, and these were weighed and added

Table 2: Mean values of moisture, pH, Protein, Fat, AKHRN, ARN, delta E and Overall Acceptability

S.No.	Meat level	S.T	D.T	Moisture	pH	Protein	Fat	AKHRN	ARN	Delta-E(BC)	OAA
1	110	12	7	10.00	5.81	23.42	4.80	620.43	114.10	7.6	6.1
2	130	12	7	12.98	5.80	24.50	6.00	692.20	118.30	9.8	6.6
3	110	18	7	9.00	5.90	22.10	3.29	710.00	108.10	8.5	6.6
4	130	18	7	10.00	5.88	22.17	5.00	774.70	112.23	9.7	6.9
5	110	12	9	8.90	6.20	22.80	4.00	803.20	111.50	9.1	6.6
6	130	12	9	9.10	6.10	23.40	5.00	882.90	117.00	9.4	6.9
7	110	18	9	7.99	6.18	20.10	3.10	810.13	110.22	8.8	6.8
8	130	18	9	9.30	6.09	23.80	4.90	880.13	116.27	9.8	7.1
9	103.18	15	8	6.20	6.25	20.26	4.00	616.90	101.80	6.9	6.2
10	136.81	15	8	10.00	5.80	27.87	6.15	938.50	125.00	9.6	6.9
11	120	15	8	8.53	5.79	26.70	6.06	825.06	121.70	8.2	6.5
12	120	9.95	8	7.90	5.90	23.20	5.20	827.10	108.90	9.8	6.9
13	120	20.04	8	12.80	5.79	27.40	6.90	700.40	122.00	7.6	6.5
14	120	15	6.32	8.90	6.00	25.00	6.10	909.80	112.50	7.8	6.8
15	120	15	9.68	7.98	5.85	24.60	5.82	771.13	115.80	8.7	6.6
16	120	15	8	7.95	5.86	24.20	5.84	773.03	115.30	8.6	6.5
17	120	15	8	7.50	5.85	24.60	5.85	785.36	115.30	8.6	6.6
18	120	15	8	8.90	5.86	24.80	5.86	787.00	115.30	8.6	6.7
19	120	15	8	7.50	5.85	24.50	5.85	785.00	115.50	8.6	6.6
20	120	15	8	8.90	5.86	24.80	5.86	777.00	116.30	8.5	6.6

S.T-Steaming time, D.T- Drying time, AKHRN-AlloKramer Hardness of Raw Noodles; ARN-Adhesiveness of raw noodles; Delta-E (BC)-Total color change before cooking; OAA-Overall acceptability

on the basis of meat + flour weight. Salt and TSPP were added first and refined vegetable oil were slowly added at the time of mixing manually. Final mixing was done in Inalsa food mixer for 1 min. Dough prepared by this way was free from connective tissues and fibers. The dough prepared in the previous section was cold extruded (pore size 3 mm for each noodle) through a hand extruder. The raw noodles were placed on multipored aluminium foil, gelatinized by steaming (as mentioned in Table 1), and finally hardened by quick chilling. Moisture content of noodles were reduced by drying in a cabinet industrial tray dryer at a constant temperature of 60°C for varying period mentioned in Table 1. The dried samples were cooled to room temperature, packed in LDPE bags, sealed and kept in controlled humidity cabinet (Sonar Plus BOD 1062M, F-0.0031900610, Associated Scientific Technologies, New Delhi, India) at ambient temperature (35±2°C, 70% R.H) before quality evaluation. The products were evaluated for moisture (automatic moisture analyzer (Essae, AND Max-50), pH (Trout *et al.* 1992), protein AOAC, (1995), fat content AOAC, (1995), AlloKramer hardness, adhesiveness (using Texture Analyzer (TMS-PRO, Food Technology Corporation, USA), total colour change (using Lovibond Tintometer (Lovibond Tintometer RT-300) and overall acceptability (Keeton, 1983).

Data analysis and modelling

A three factor three level central composite design with five replicates at centre point and total twenty number of combinations (meat level: 110-130g, steaming time: 12-18 min, drying time: 7-9 hrs) (Table 2) were used to develop predictive models for physicochemical parameters. The following second order polynomial equation of function X_i was fitted for each factor assessed:

$$Y = \beta_0 + \sum_{i=1}^{k} \beta_i X_i + \sum_{i=1}^{k} \beta_{ii} X_2 + \sum_{i>j}^{k} \beta_{ij} X_i X_j$$

From the equation presented, *Y* may be defined as the response for the variables assessed, βo, β_i, β_{ii} and β_{ij} are the equation parameter estimates (β_o a constant, *i* a parameter estimate for linear terms, β_{ii} an estimate for quadratic terms and β_{ij} an estimate for interactive terms). *i* and *j* are the levels of the factors with k being the number of factors assessed. In the centre point of model where medium levels of three independent variables were represented, experimental combination were performed five times (15th-20th runs) to estimate experimental variance.

The majority of generated models adequately explain variation of responses with satisfactory R^2 values (R^2>0.90) and Modal F-value, which indicated that most variations could be well explained by the quadratic models and can be considered adequate, because the probability level of F was P<0.01. The computational work, including the surface and contour graphical presentations of response surface models, analysis of variance (ANOVA) and other statistical analysis was performed with 0.05 significance level using STAT-EASE software design expert 8.0.4 trial version.

RESULTS AND DISCUSSION

Product Characteristics

Raw noodles after extrusion were white in colour, sticky in nature with 3 mm diameter and 10-15 cm in length approximately. This white colour and adhesiveness attributed to addition of refined wheat flour and meat respectively, but after steaming colour changes to brown and adhesiveness decreases, might be due to gelatinization of starch. On drying at 60°C for 7-9 hrs noodles becomes hard due to complete dehydration. Dried noodles then water cooked for 5 minutes, water cooked noodles exhibits white colour and other highly acceptable sensory qualities and are ready to serve.

Model fitting from RSM

The effects of meat level and processing conditions on moisture, pH, protein, fat content, AlloKramer hardness, adhesiveness, total colour change and overall acceptability are shown in Table 2. The independent and dependent variables were fitted to the second-order model equation and examined for the goodness of fit. Second order polynomial equation can be used to determine response for any combination by substituting values of independent variables and regression coefficients and their interaction (Table 4). The analyses of variance were performed to determine the lack of fit and the significance of the linear, quadratic and interaction effects of the independent variables on the dependent variables (Table 3). The lack of fit test is a measure of the failure of a model to represent data in the experimental domain at which points were not included in the regression (Varnalis *et al.* 2004). Coefficient of determination or R^2 is the proportion of variation in the response attributed to the model rather than to random error and was suggested that for good fit model, R^2 should be at least 80%. The results showed that the models for all the response variables were highly adequate because they have satisfactory levels of R^2 of more than 80% and that there is no significant lack of fit in all the response variables. The regression coefficients are shown in Table 4 and the equations for each of the response variables could be derived from the predicted values of each response variable. The R^2 values of all of the responses exceeded 80 % indicating a high proportion of variability as explained by the data. Therefore, the response surface models developed were adequate.

Effect of meat level, steaming and drying time

Diagnostic checking of fitted model for moisture

Regression analyses for model were conducted through CCD of response surface methodology (RSM) and it indicates that fitted model accounted for more than 80% of variation in experimental data, which were highly significant. Second order polynomial equation generated relating moisture (%) based on three independent variables (Meat level, steaming time and drying time) as under:

$$\text{Moisture (\%) (Y)} = 45.294 + 0.0696X_1 - 3.778X_2 - 3.535X_3 - 0.010X_1X_2 - 0.011X_1X_3 + 0.136X_2X_3 + 1.077X_1^2 + 0.120X_2^2 + 0.148X_3^2 \quad (df = 9, R^2 = 0.91)$$

Second order polynomial equation can be used to determine response (moisture) for any combination by substituting values of independent variables and regression coefficients and their interactions. Correlation coefficient of R^2=0.91 and Model F-value of 12.07 as mentioned in Table (3) of analysis of variance exhibited that response surface model for moisture level is highly significant. According to final equation table (4) meat level had positive linear and quadratic effect on moisture content of chicken noodles (Figure 1). This could be attributed to added water and free water present in meat.

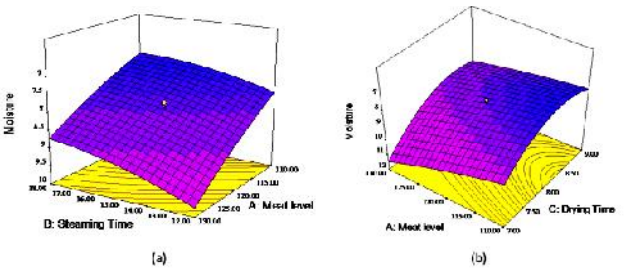

Fig. 1: Effect of a) meat level and steaming time b) meat level and drying time on moisture of chicken meat noodles

Water uptake by muscle tissues during tenderization process could also not be ruled out. Steaming and drying time had negative quadratic effect (Figure 1). Similarly, interactions between meat level and drying time and meat level and steaming time were exhibited significantly negative effect which might be due to loss of moisture during steam cooking (12-18 min) and subsequent drying at 60°C for 7-9 hrs. Rhee *et al.* (1999) reported that spent hen meat contains more moisture than other species meat (lamb, beef and mutton) when they were prepared extrudates blends from different species meat. The increased moisture percent with increase in meat level might be due to high moisture contents in chicken meat as compared to the flour used (Verma *et al.* 2014). They also reported that moisture loss increases after extrusion because of post extrusion drying. Literature related to chicken noodles is scanty; however, Zweifel *et al.* (2003) reported decrease in moisture level of durum wheat pasta after 8-10 hrs drying at 55-100°C at three levels.

Diagnostic checking of fitted model for pH

Second order polynomial equation generated relating product pH and three independent variables (meat level, steaming time and drying time) is shown as under:

$$\text{Product pH (Y)} = +15.866 - 0.181X_1 + 0.081X_2 + 0.076X_3 - 6.666X_1X_2 + 1.727X_1X_3 - 8.333X_2X_3 + 7.659X_1^2 + 4.112X_2^2 + 3.403X_3^2 \quad (\text{df}=9, R^2 = 0.81)$$

The correlation coefficient of $R^2 = 0.81$and Model F-value of 4.76 as mentioned in Table of analysis of variance indicated that response surface model for product pH is highly significant. According to final equation (Table 4) product pH was significantly decreased with the increase of meat level, and this is attributed to the acidic pH of meat Similar results were reported by Verma *et al.* (2014) who also found decrease in pH with increase in meat level in chicken meat noodles. Steaming time had positive quadratic effect on pH of product at ($p<0.5$). This could be due to steaming itself increases pH of noodles that formed during gelation, the pH of steam varied from neutral to alkaline side. Drying time also had positive significance which might be due to dissociation of water molecules into hydrogen ion and hydroxyl radical on drying at 60°C and both ions contributes to increase in pH of product. The interaction between meat level and steaming time had a negative effect on pH (Figure 2). This could be due to dehydration reaction during steaming of raw noodles as reduction of water level leads to slight decrease in pH. However, meat level and drying time interaction had positive quadratic effect. Response surface models and contour plots were obtained by selecting two variables and product pH.

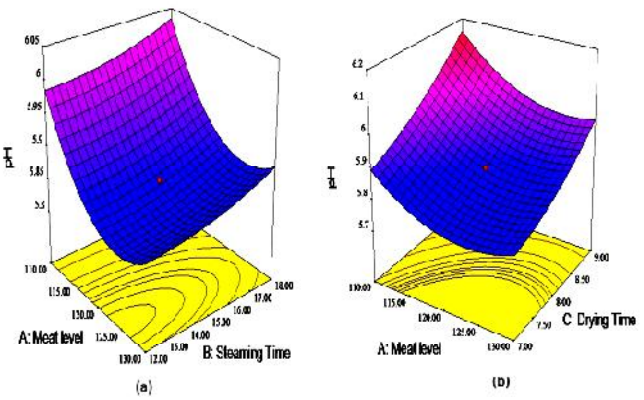

Fig. 2: Effect of a) meat level and steaming time b) meat level and drying time on pH of chicken meat noodles

Diagnostic checking of fitted model for protein

Second order polynomial equation generated in relation to protein content and three independent variables (meat level, steaming time and drying time) is shown as under:

Table 3: F-values and effect of independent variables on responses

S.V	df	Moisture	pH	Protein	Fat	AKHRN	ARN	Delta-E	OAA
Linear									
X1	1	25.15	8.61	15.86	13.06	28.83	16.26	20.78	84.68
X2	1	31.28	21.22	1.82	3.69	1.36	22.34	3.14	44.71
X3	1	5.89	0.52	5.02	1.77	36.55	23.30	149.47	37.04
Interaction									
X12	1	1.86	0.39	0.03	0.44	0.02	5.02	0.04	0.87
X13	1	0.23	0.00	1.29	3.10	0.01	0.09	1.83	0.87
X23	1	3.25	0.62	0.20	0.58	2.03	3.48	0.20	3.48
Quadratic									
X11	1	0.41	10.42	2.39	8.22	0.48	0.65	0.087	0.04
X22	1	40.91	1.67	0.30	3.24	0.75	2.90	4.53	6.02
X33	1	0.77	0.03	0.46	0.02	0.04	0.09	1.11	2.46
Residual	10								
Lack of Fit	5	8.47	539.72	86.85	3482.12	71.80	32.55	0.82	1.87
Pure Error	5								
Cor Total	19								
R2		0.91	0.81	0. 83	0.81	0.87	0.91	0.82	0.94
Modal F-value		12.07	4.76	3.05	3.35	7.80	7.68	3.67	19.98

df-Degree of freedom; AKHRN-AlloKramer Hardness of Raw Noodles; ARN-Adhesiveness of raw noodles Delta-E (BC)-Total color change before cooking OAA-Overall acceptability

$$\text{Protein (Y)} = -26.242 + 1.007X_1 - 2.400X_2 - 2.400X_3 + 0.054X_1X_2 + 2.708X_1X_3 - 0.073X_2X_3 - 5.579X_1^2 - 0.245X_2^2 + 0.021X_3^2 \quad (df = 9\ R^2 = 0.83)$$

Regression coefficients of this response for all variables along with their interactions are presented in Table 4, and by substituting these coefficients and independent variables in second order polynomial equation, optimum values for protein content can be determined. Correlation coefficient of $R^2 = 0.83$ and Modal F-value of 3.05 (Table 3) implies that response surface model is highly significant. Meat level had positive linear and quadratic effect at 95 percent confidence level on protein content of chicken noodles due to more protein content in meat (19-25%). Kale, 2009 also found highly significant ($P<0.01$) difference in protein content in chicken meat stick and found that there was increase in protein content while increase in incorporation of meat in chicken meat stick. Similar trend of increased protein contents with increase in fish meat in fish noodles was also reported by Yu (1990). The interaction of meat level × steaming time had significantly positive effect, while interaction between drying time × steaming time had significantly negative effect on protein content which could be due to loss proteins on processing. Response surface models and contour plots obtained by selecting two variables and response and these models are presented in Figure 3. The experimental values and predicted values did not not show any significant difference, which indicated goodness of fitted model and strength of response towards model.

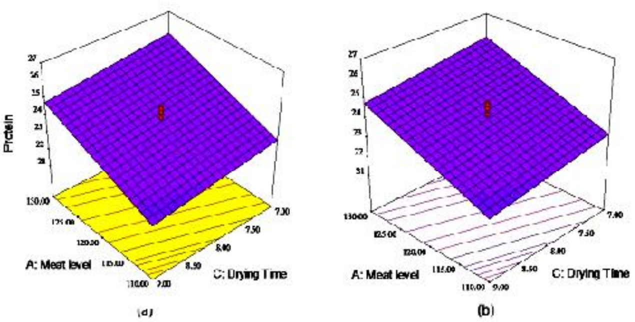

Fig. 3: Effect of a) meat level and steaming time b) meat level and drying time on on protein of chicken meat noodles

Table 4: Regression coefficients of second order polynomial equations showing relationships among response variables and independent variables

Coefficient	Moisture	pH	Protein	Fat	AKHRN	ARN	Delta-E	OAA
Intercept								
β0	+45.29	+15.87	-26.24	-68.15	-2090.92	+113.85	28.79	-0.60
Linear								
β1	+0.07	-0.18	+1.01	+1.26	+24.06	+0.77	+0.19	+0.06
β2	-3.78	+0.08	-2.40	-0.17	+37.11	-1.18	-0.55	+0.11
β3	-3.53	+0.08	-0.56	-0.65	+120.16	-10.82	+6.15	+0.17
Interaction								
β12	-0.01	-6.67	+0.05	+5.46	-0.07	+1.25	-1.25	-8.33
β13	-0.01	+1.73	+2.71	-1.37	+0.16	+0.01	-0.15	-2.50
β23	+0.14	-8.33	-0.07	+0.06	-6.99	+0.33	-0.03	-0.02
Quadratic								
β11	+1.08	+7.66	-5.58	-5.27	-0.08	-3.18	+4.25	-4.04
β22	+0.12	+4.11	-0.24	-0.04	+1.05	-0.07	+0.03	+5.44
β33	+0.15	+3.40	+0.02	-0.02	+2.07	+0.12	-0.03	+0.03

AKHRN-Allokramer Hardness of Raw Noodles; ARN-Adhesiveness of raw noodles Delta-E (BC)-Total color change before cooking OAA-Overall acceptability.

Diagnostic checking of fitted model for Fat

The second order polynomial equation generated in relation to fat content and three independent variables (meat level, steaming time and drying time) is given as under:

Fat **(Y)** = $-68.159 + 1.263X_1 - 0.175X_2 - 0.653X_3 + 5.458X_1X_2 - 1.375X_1X_3 + 0.062X_2X_3 - 5.273X_1^2 - 0.036X_2^2 - 0.023X_3^2$ (df = 9 $R^2 = 0.81$)

Regression coefficients of this response for all variables along with their interactions are presented in Table 4. By substituting regression coefficients and independent variables in second order polynomial equation, optimum values for fat (%) of noodles can be determined. Correlation coefficient of $R^2 = 0.81$ and Model F-value of 3.35 (Table 3) indicated that response surface model for fat percent is highly significant. According to final equation Table 3 all variables and their interaction had significant effect on this response. Meat level alone and its interaction with steaming time had significantly positive effect, and this could be due to fat level of meat, as meat level increased the noodle formulation fat content also increased. Meat level and drying time interaction had negative quadratic effect on fat percent Figure 4 which could be due to loss and degradation of fat during heat processing. Asma *et al.* 2015 studied the effect of superheated steam cooking on fat content of chicken sausage and found linear decrease in fat content with increase in steam cooking temperature.

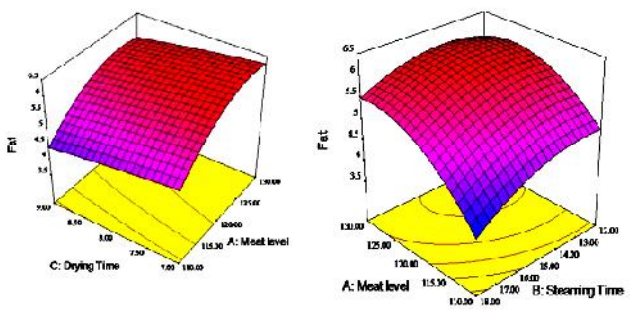

Fig. 4: Effect of a) meat level and steaming time b) meat level and drying time on on fat of chicken meat noodles

Diagnostic checking of fitted model for Energy/ adhesiveness of raw noodles

The second order polynomial equation generated in relation to adhesiveness and three independent variables (meat level, steaming time and drying time) is shown as under:

Adhesiveness **(Y)** $= +113.849 + 0.777X_1 - 1.183X_2 - 10.828X_3 + 1.250X_1X_2 + 0.016X_1X_3 + 0.329X_2X_3 - 3.178X_1^2 - 0.074X_2^2 + 0.124X_3^2$ (df =9 R^2 = 0.91)

Correlation coefficient of R^2 = 0.91 and Model F-value of 7.68 (Table 3) exhibited that response surface model for adhesiveness is highly significant. According to final equation Table 4 all variables and their interaction had significant effect on this response. Meat level had linear and positive quadratic effect at (p<0.5) on adhesiveness of products Figure 5. This could be attributed to moisture content as well as carbohydrates present in meat. Interaction in between steaming × drying time had significantly negative effect on adhesiveness values of product which could be due to loss of moisture during steam cooking. Pronyk *et al.* (2008) also reported that adhesiveness of noodles was decreased with the increased in processing time. The interaction between meat level × steaming time had positive effect which could be attributed to dominating effect of meat level over steaming time, as meat consist of protein, water and fat which combines with flour increases stickiness of product. Similarly meat level × drying time interaction also increased adhesiveness. Interaction of drying time × steaming time also had positive effect on adhesiveness, this could be due to moisture absorption by the noodles during steam cooking.

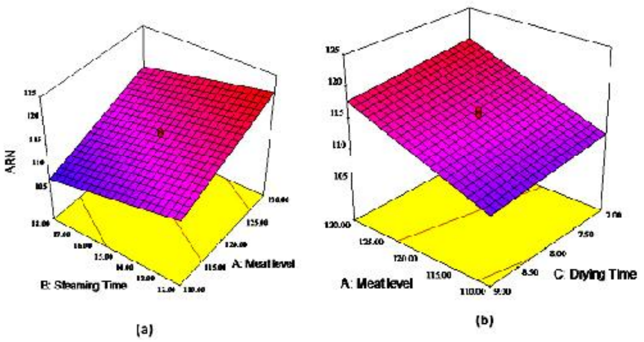

Fig. 5: Effect of a) meat level and steaming time b) meat level and drying time on adhesiveness of chicken meat noodles

Diagnostic checking of fitted model for Allo-Kramer hardness of raw noodles

The second order polynomial equation generated in relation to Allo-Kramer shear hardness of products and three independent variables (meat level, steaming time and drying time) is shown as under:

Allo-Kramer hardness **(Y)**$= -2090.923 + 24.062X_1 + 37.114X_2 + 120.162X_3 + 120.162X_1X_2 + 0.165X_1X_3 - 6.996X_2X_3 - 0.076X_1^2 + 1.054X_2^2 + 2.070X_3^2$ (df = 9 R^2 = 0.87)

Regression coefficients of this response for all variables along with their interactions are mentioned in Table 4, and substituting these coefficients and independent variables in second order polynomial equation, optimum values for Kramer hardness of raw noodles can be determined. Correlation coefficient of R^2=0.87 and Model F-value of 7.80 (Table 3) of analysis of variance implies that response surface model for Kramer hardness of raw noodles is highly significant. According to final equation (Table 4), all independent variables along with their interactions are significantly differed. The interaction between meat level × steaming time had negative effect at (p<0.5) which could be due to denaturation of meat protein by steam treatment. However interaction between meat level × drying time had significantly positive effect where both variables act synergistically and leads to increased in Kramer hardness of raw noodles Figure 6. Drying leads to denaturation of wheat protein glutenin and gliadin and promotes formation of strong glutein network which is responsible for firmness of noodles. Interaction between drying time × steaming time exhibited negative effect on this response. Superheated steam is generated from the addition of sensible heat to water, this lead to increase its temperature over boiling point or saturation temperature at the given pressure (Zzaman *et al.* 2013) and this constant increase of temperature by steaming is reason for hardness of noodles,

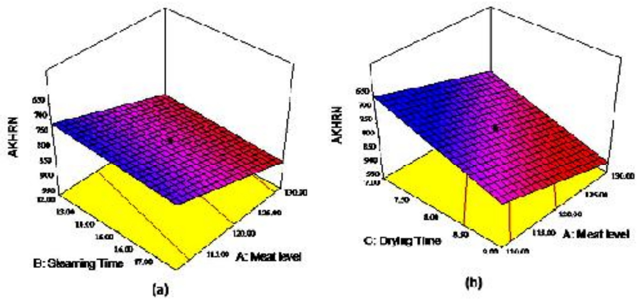

Fig. 6: Effect of a) meat level and steaming time b) meat level and drying time on allokramer hardness of chicken meat noodles

Diagnostic checking of fitted model for Total colour change delta-E (ΔE) of raw noodles

Second order polynomial equation generated relation to ΔE and three independent variables (meat level, steaming time and drying time) is shown as under:

Total colour change (Y) = $-28.787 + 0.194 X_1 - 0.554X_2 + 6.152X_3 - 1.250 X_1X_2 - 0.151X_1X_3 - 0.029X_2X_3 + 4.254X_1^2 + 0.034X_2^2 - 0.026X_3^2$ (df=9, R^2=0.82)

Correlation coefficient of R^2 = 0.82 and Model F-value of 3.67 are quite high for response surface (Table 3) of analysis of variance and it implies that response surface model for ΔE is highly significant. Interactions between meat level × steaming time and meat level × drying time had positive effect on ΔE value due to increase in both redness (*a*-value) and yellowness (*b*-value) with the increase in processing time Figure 7. The ΔE value was increased in chicken noodles with the increase in meat level because of myoglobin content in meat which resulted in increase of *a*-value (redness) thereby ΔE value. Pronyk *et al.* (2008) reported that with the increase in steaming time all the colour coordinates (*L*, *a*- and *b*-values) decreased significantly. Interaction between drying and steaming time showed negative effect on ΔE value.

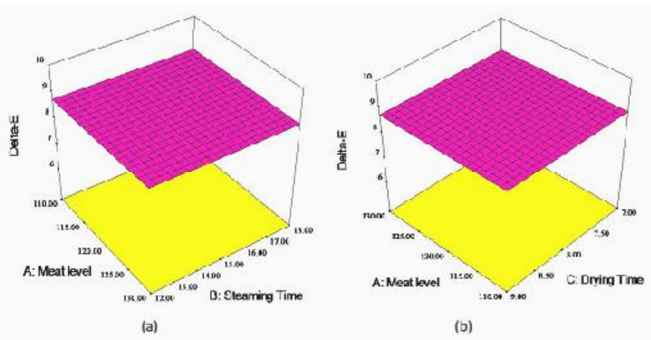

Fig. 7: Effect of a) meat level and steaming time b) meat level and drying time on Delta-E of chicken meat noodles

Diagnostic checking of fitted model for Overall acceptability (OAA)

The second order polynomial equation generated in relation with overall acceptability and three independent variables (meat level, steaming time and drying time) is shown as under:

Overall acceptability (Y) = $-0.602 + 0.061X_1 + 0.115X_2 + 0.173X_3 - 8.333X_1X_2 - 2.500X_1X_3 - 0.016X_2X_3 - 4.036X_1^2 + 5.444X_2^2 + 0.031X_3^2$ (df =9, R^2 = 0.94)

Second order polynomial equation can be used to determine response (OAA) for any combination by substituting values of independent variables and regression coefficients of variables and their interaction as given in Table 3. Correlation coefficient of R^2 = 0.94 and Model F-value of 19.98 are quite high for response surface as mentioned in Table 2 of analysis of variance and it implies that response surface model for OAA is highly significant. Overall acceptability was evaluated on basis of colour and appearance, flavour, texture, meat flavour intensity and after taste. Multiple regression analyses indicated that all independent variables along with their interactions significantly affecting overall acceptability. Textural properties were more favourable for steam cooked noodles, steaming increases hardness of raw noodles so ability to absorb water increases after cooking while adhesiveness or stickiness decreases, hence both the conditions makes noodles more palatable (Pronyk *et al.* 2008).

Interaction between meat level × steaming time and meat level × drying time had negative effect on overall acceptability; it may be due to excessive denaturation of soluble meat protein during heat processing which ultimately leads to slight loss of flavour. Drying and steaming time interaction also exhibited negative effect on OAA scores. Response surface models and contour plots obtained by selecting two variables and response (OAA) Figure 8.

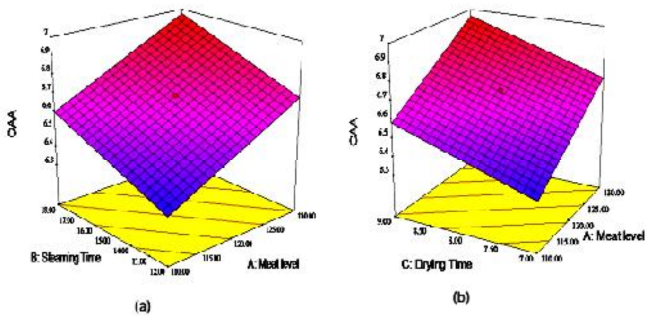

Fig. 8: Effect of a) meat level and steaming time b) meat level and drying time on OAA of chicken meat noodles

Table 5: Desirability of product based on response surface methodology (RSM)

No.	M. L	S.T	D.T	Moisture	pH	Protein	Fat	AKHRN	ARN	Delta-E	OAA	Desirability	
1	120	15.00	9.00	8.21	5.99	23.50	5.60	851.70	113.62	8.75	6.77	0.824	Selected
2	120	15.04	9.00	8.21	5.99	23.49	5.60	851.87	113.589	8.75	6.77	0.822	
3	120	15.00	8.99	8.19	5.99	23.515	5.60	850.73	113.636	8.749	6.77	0.821	

M.L- Meat Level; S.T-Steaming Time; D.T-Drying Time; AKHRN-Allo Kramer Hardness of Raw Noodles; ARN-Adhesiveness of raw noodles Delta-E (BC)-Total color change before cooking OAA-Overall acceptability.

Optimization

The optimum formulations were selected and used for calculating the predicted values of response variables using the prediction equations derived by RSM. Finally desirability table (Table 5) and graphs (Figure 9) obtained and more than 82% desirability were selected which gives optimized meat level and processing conditions. Based on these desirability plots, it is suggested that the optimum formulation of chicken meat noodles was meat level 120 g (60%), steaming time 12 min and drying time 9 hr. Once the optimum formulation was determined, they were used to produce chicken meat noodles and all the response variables of the final products were analysed. The experimental and predicted values were within the range and found to be not statistically different at 5% level. Thus, the model can be used to optimize the basic formulation of chicken meat noodles.

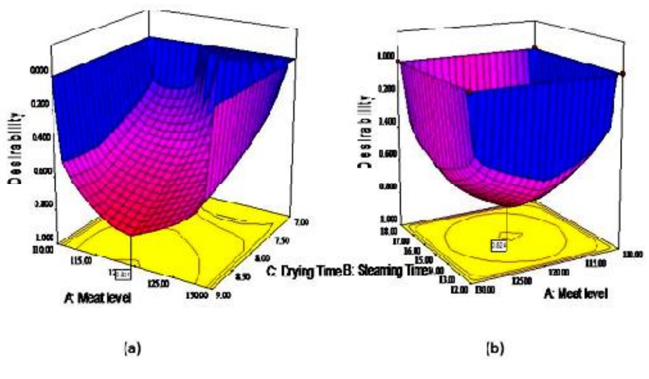

Fig. 9: Effect of a) meat level and drying time b) meat level and steaming time on desirability of chicken meat noodles

CONCLUSION

RSM is a useful tool in optimization of the basic formulation of chicken meat noodles. Meat level and processing conditions significantly affects dependent variables. The model equation developed can be used for predicting the quality of chicken meat noodles. Based on the desirability plots 60% meat level 12 min steaming and 9hrs drying time was found to be optimized.

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CONFLICT OF INTEREST

Authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

A.K.K wrote the article and corrected it. A.K.K, A. K.B, J.S and M.K.C designed the study. A.K.K. conducted the experimental work. S.B helped in RSM analysis.

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